SUNRISE:
A New Stratospheric Platform for High Resolution Solar Observations

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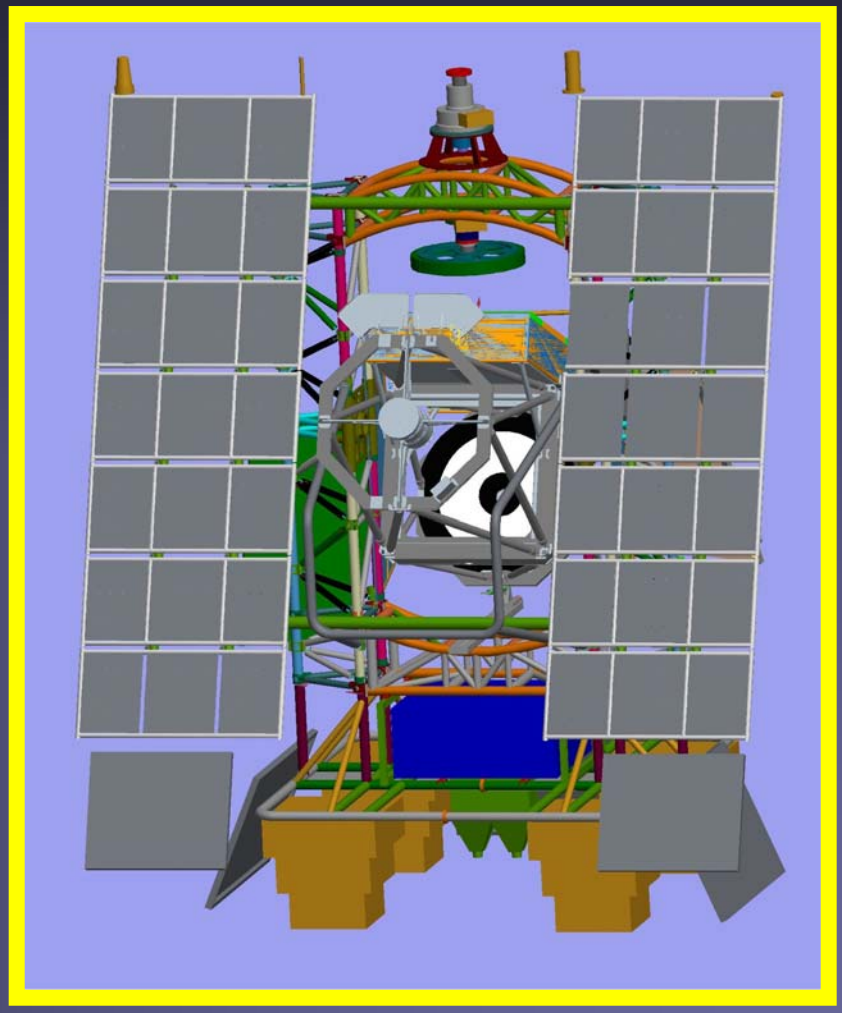
SUNRISE in Brief

- **Aim:** study magneto-convection at a resolution of up to 35km on the Sun
- **Observables:** time series of diffraction limited UV images, visible magnetograms & NIR polarized spectra
- **Instrument:** 1-m balloon-borne telescope, with 3 simultaneously observing postfocus instruments
- **Mission:** fly in a series of long-duration balloon flights on circumpolar trajectories



SUNRISE Lead Scientists

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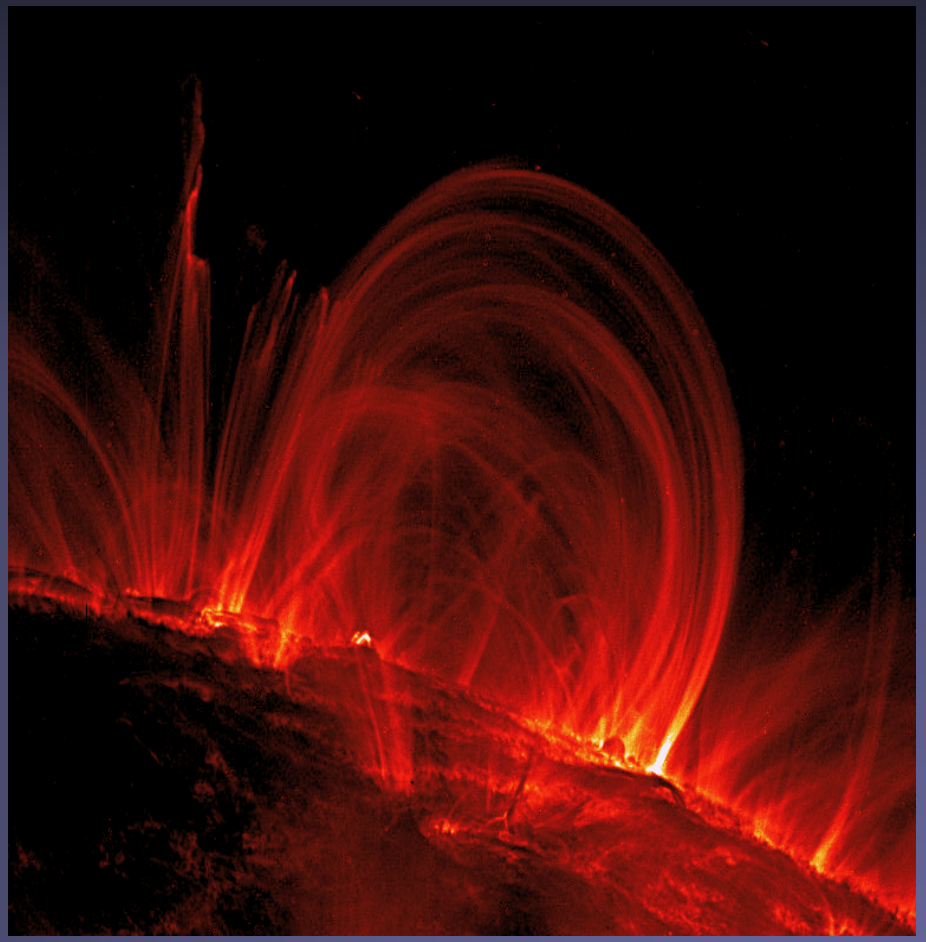
SUNRISE Science

- Study of solar magnetic field
- Investigate photospheric and chromospheric phenomena
- Resolve time dependent characteristics of magneto-convective patterns
- Analyze small scale interaction of convective flows and magnetic field
- Test predictions by MHD simulations and new discoveries



Key Science Questions

- How is the magnetic field brought to and removed from the solar surface? How does it develop there?
- What are the origin and the properties of the intermittent magnetic structure in the photosphere?
- How does the field provide/transport momentum and energy to the outer solar atmosphere?
- What is the underlying physics of the solar UV irradiance variability?
- What is the physical nature of the solar chromosphere? How is the chromosphere heated?

SUNRISE Basic Requirements

- Resolve scale of magnetic elements (<50 km, <0.05”) with sufficient field of view

  → Diffraction limited telescope with 1 meter aperture
  → Above atmosphere to cancel seeing effects and to access the UV
  → High precision pointing + image stabilization

- Resolve (≤5 s) and cover (hours - days) their evolution
  → High cadence + uninterrupted observations

- Measure 3D-distribution of B vector, v, T
  → Polarization sensitive spectroscopy in photospheric/chromospheric line(s)

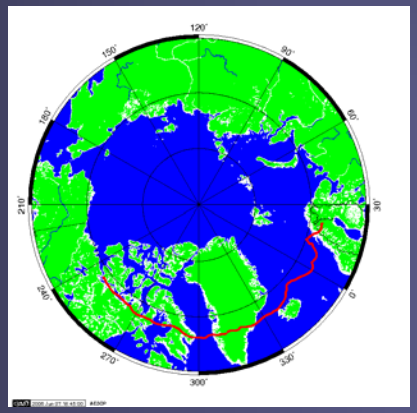
- High-cadence imaging of different layers
  → Visible + UV filtergrams

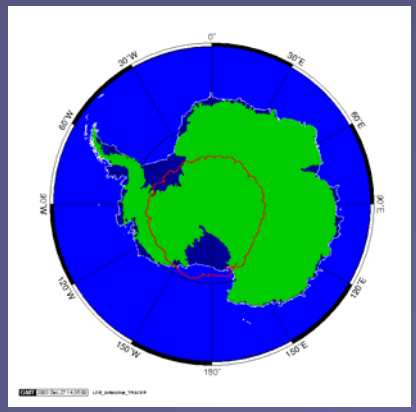
SUNRISE Mission

NASA LDB Flight Program:

- Science payload weight ~1800 kg
- 29.47 MCF, ~ 835000 m^3
  Zero pressure balloon
- Float altitude 35 km – 40 km
- No seeing, UV region accessible

- Launch Sites
  ESRANGE / Sweden (preferred)
  (67.89°N, 21.10°E)
  or
  Williams Field / Antarctica
  (77.86°S, 167.13°E)

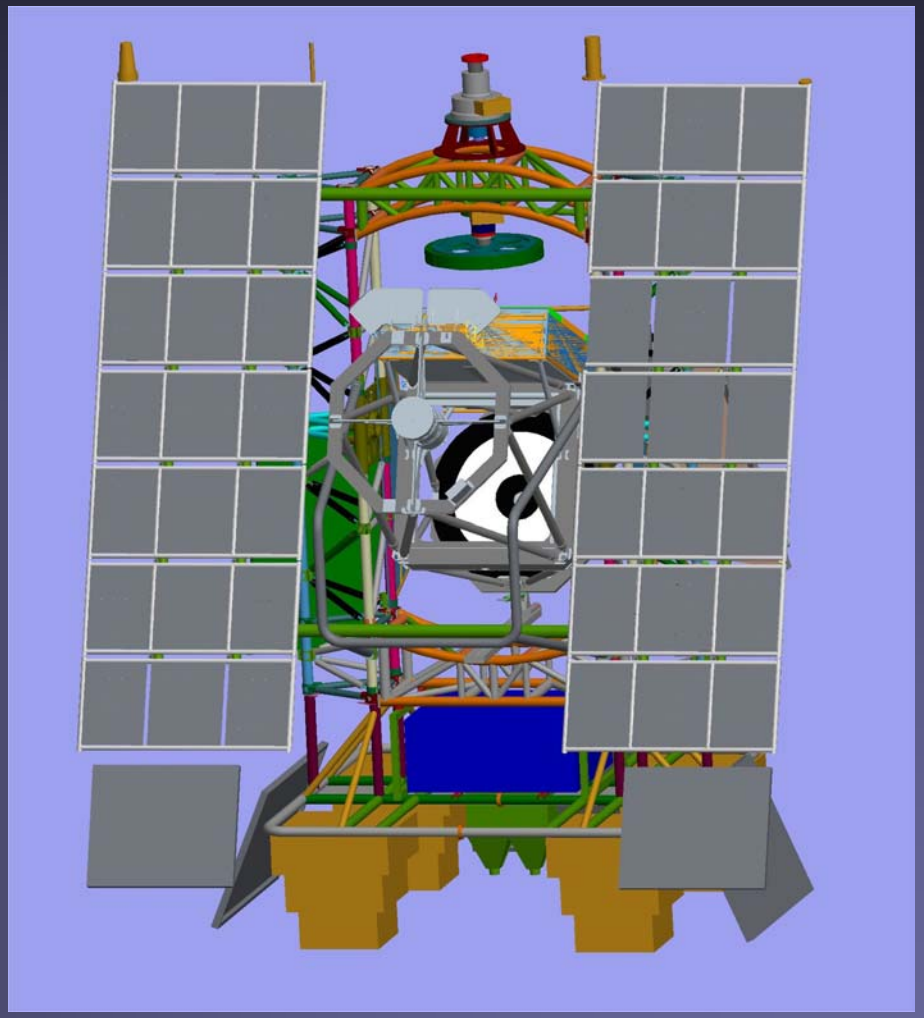




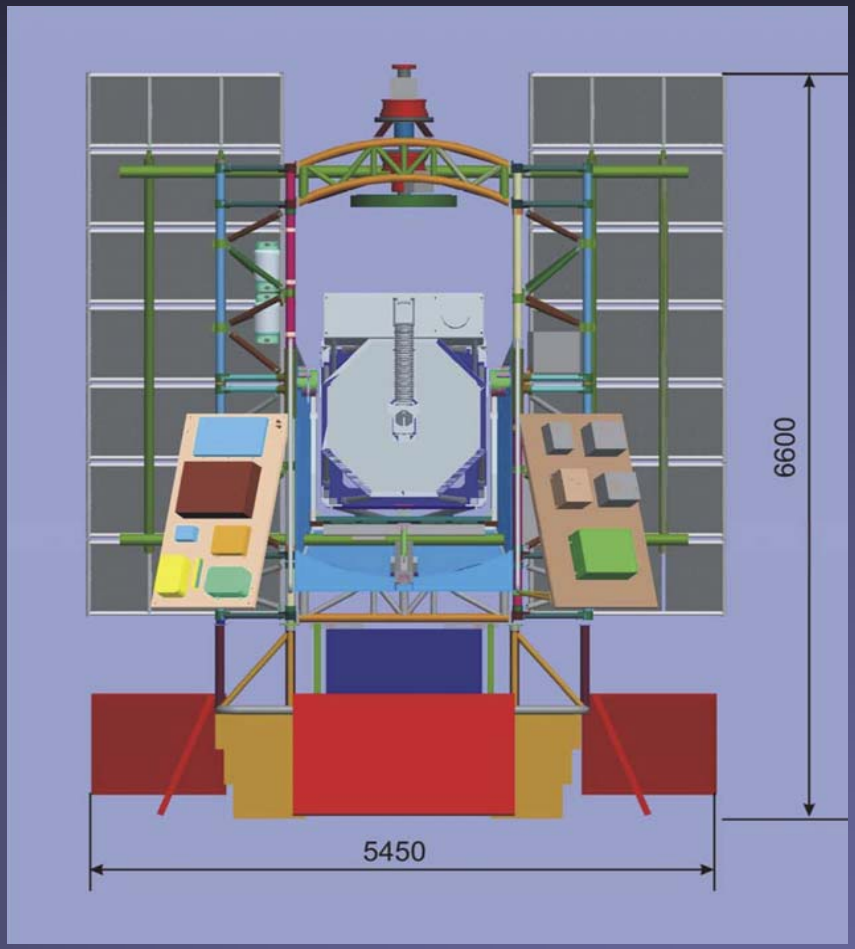
- Circumpolar trajectories during
  Solstice conditions allow uninterrupted solar observations

SUNRISE Gondola

- Platform for the telescope and science instruments
- Azimuth/elevation stabilization to few arcsec accuracy
- Power supply (solar panels and batteries)
- Commanding / communication from / to ground via CSBF provided SIP (Science Instrumentation Package)
- Transparent Ethernet connection for LOS telemetry (<500 km) using ESRANGE developed E-Link system



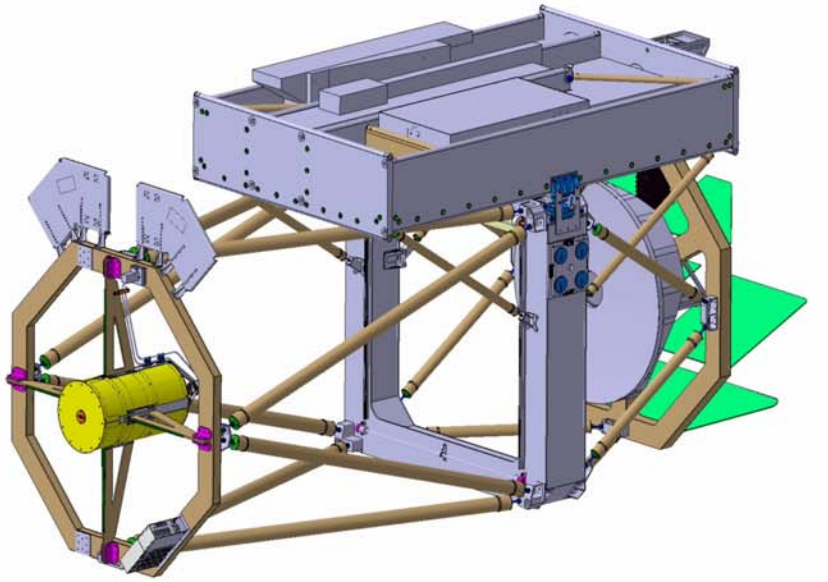
SUNRISE Gondola



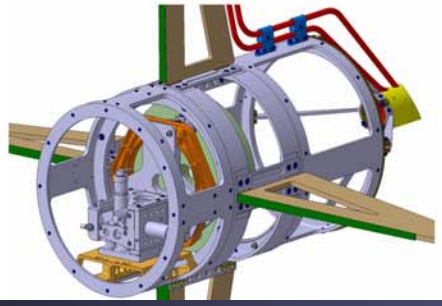
SUNRISE Telescope

- Industrial contract (Kayser-Threde, Munich)
- Carbon fiber based Serrurier telescope structure
- Lightweighted Zerodur primary mirror (SAGEM, France), f=2.5 m parabola with 1 meter aperture
- Gregory configuration with intermediate field stop, F/25
- Field of view: 3.4 arcmin (150 Mm on the Sun)
- In-flight alignment: M2 adjustable in 3 degrees of freedom, controlled by a wavefront sensor
- Two plane fold mirrors (M3, M4) to feed postfocus instrumentation (movable for fine focus)

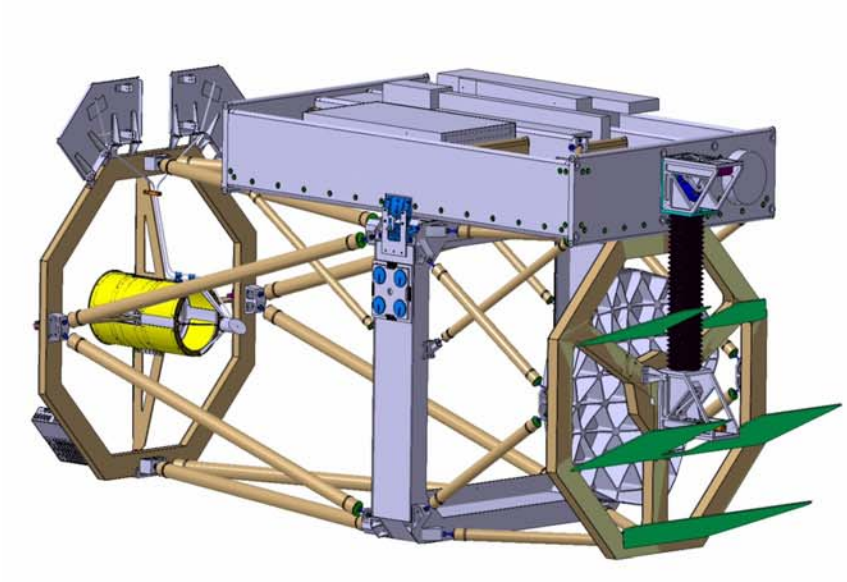
SUNRISE Telescope



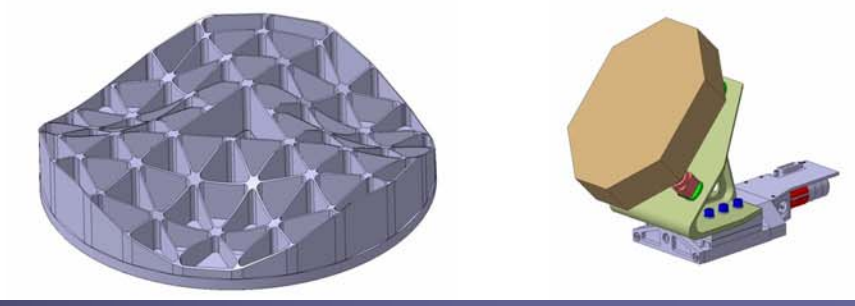
Secondary mirror on 3axis translation stage



M2 housing with heat rejection wedge



Rear side of lightweighted Zerodur primary mirror

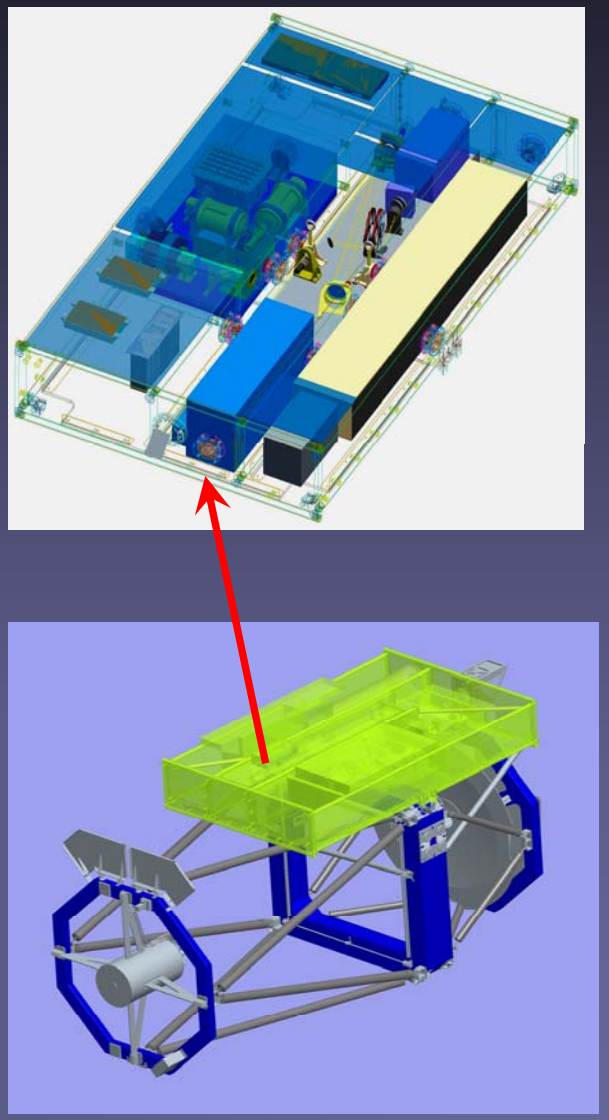


M3 on translation stage

SUNRISE Instrumentation

Three Science Instruments:

- UV Filtergraph: **SUFI**
  - Multi-wavelength phase diversity imager
  - 225nm, 280nm (Mg II h/k), 300nm, 313nm (OH), 388nm (CN)
- Imaging Magnetograph: **IMaX**
  - Fabry-Perot etalon & liquid crystal modulators
  - 2D maps of the magnetic vector + Dopplergram
  - 525nm (Fe I), 60 mÅ resolution
- Polarimetric Spectrograph: **SUPOS**
  - Dual-beam spectro-polarimeter in Ca II (854 nm) and Fe I (853.8 nm)

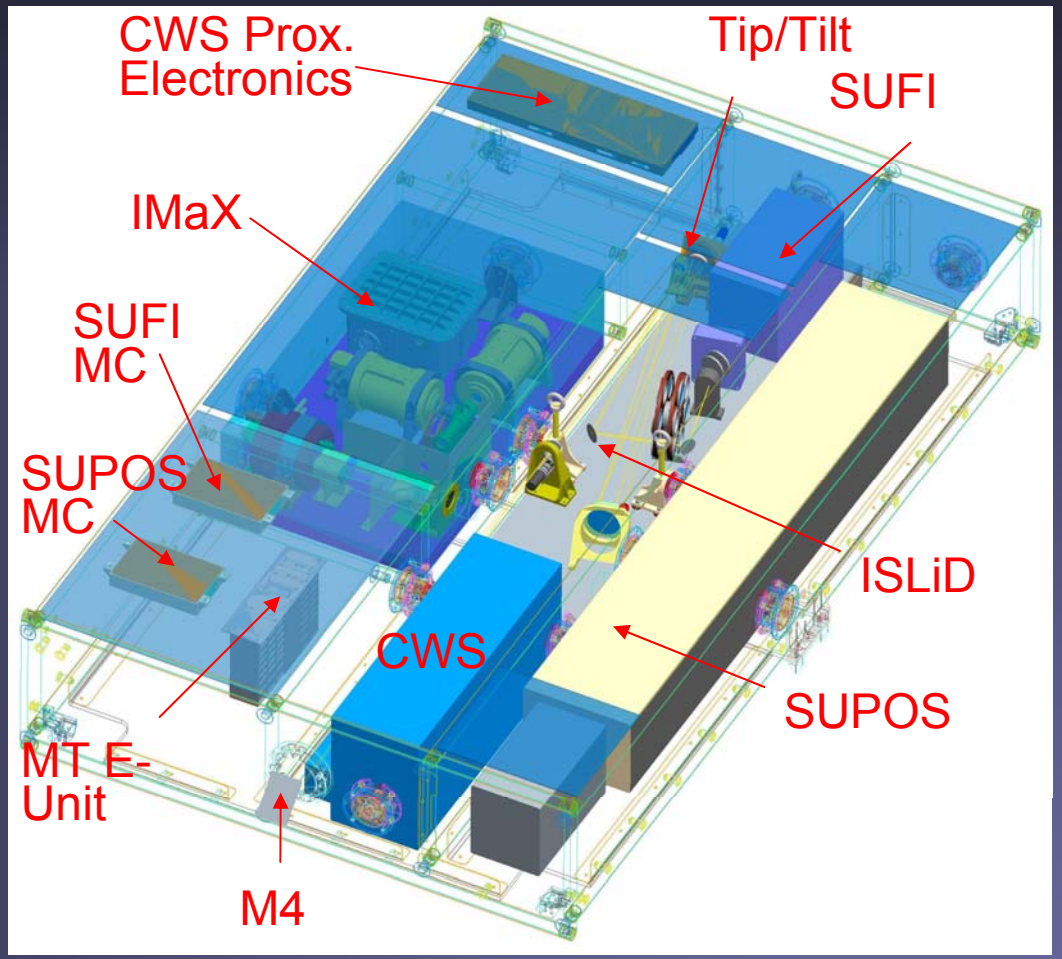


Two Service Modules:

- Image stabilization and light distribution unit: **ISLiD**
- Correlation tracker and wavefront sensor: **CWS**

SUNRISE Instrumentation

- Postfocus instrumentation sits „piggy-back“ on telescope
- Carbon fiber based honey-comb structure for high stiffness and low thermal expansion
- Pre-aligned instrument „modules“
- Fast tip/tilt mirror @ pupil image for image stabilization
- Individual radiators for heat dissipators



SUNRISE Hardware Status

Gondola

Preparation for fall 2007 test flight in Ft. Sumner, New Mexico, USA

Current activities are:

- Assembly of the framework core structure
- Attaching the roll cages and solar panel dummies
- Preparing the pointing computer electronics and software
- Testing of azimuth drives and control loops
- Assembly of the test flight telescope

SUNRISE Hardware Status

Electronics

- Instrument Control System
  - Main on-board control computer
  - Data storage units (2x 2.4TByte)
  - Power distribution units
  - harness

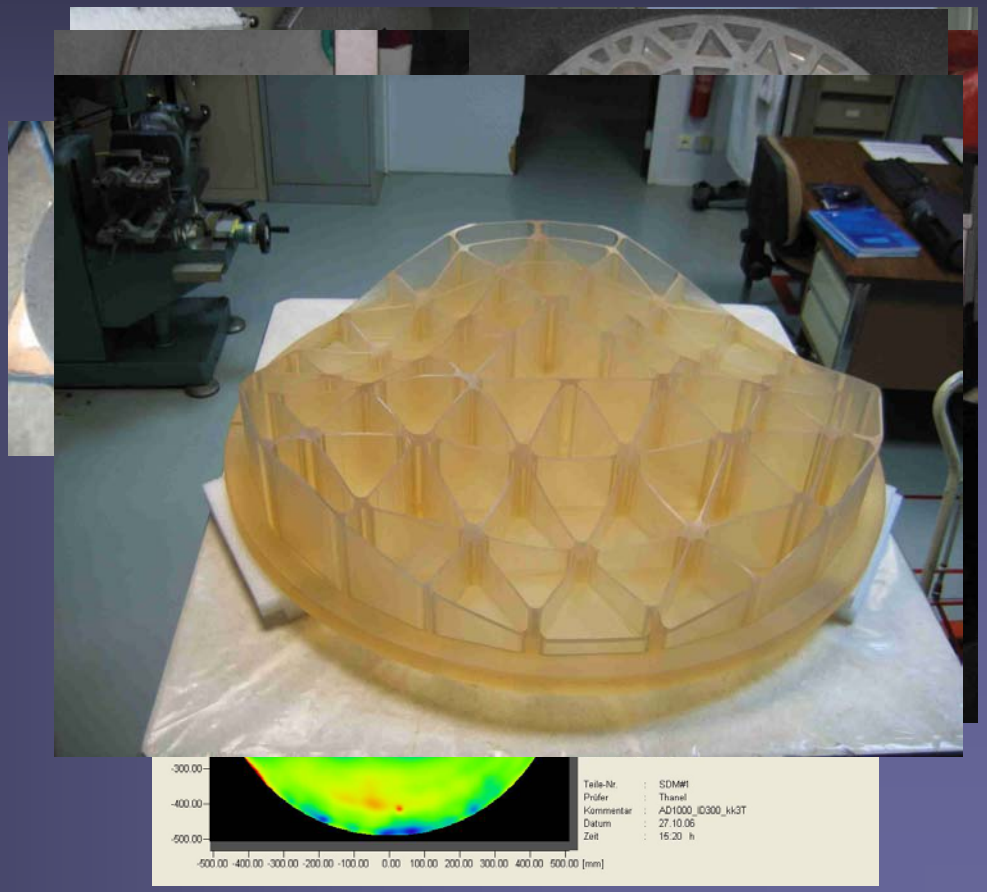
  qualified, tested, ready for flight
- Being shipped to HAO for system integration this week
- E-Link rental contract signed, frequency permission given by NTIA

SUNRISE Hardware Status

Primary Mirror

- CDR procedure finished in Sept 2006, manufacturing release
- Rear side shaping finished Dec 2006
- Lightweighting finished April 2007
- Grinding / polishing of parabolic front face ongoing
- Expected delivery date to telescope manufacturer Dec 2007

- Mirror alternative on silicon carbide (Cesic) basis in progress for a future 2nd SUNRISE flight



SUNRISE Hardware Status

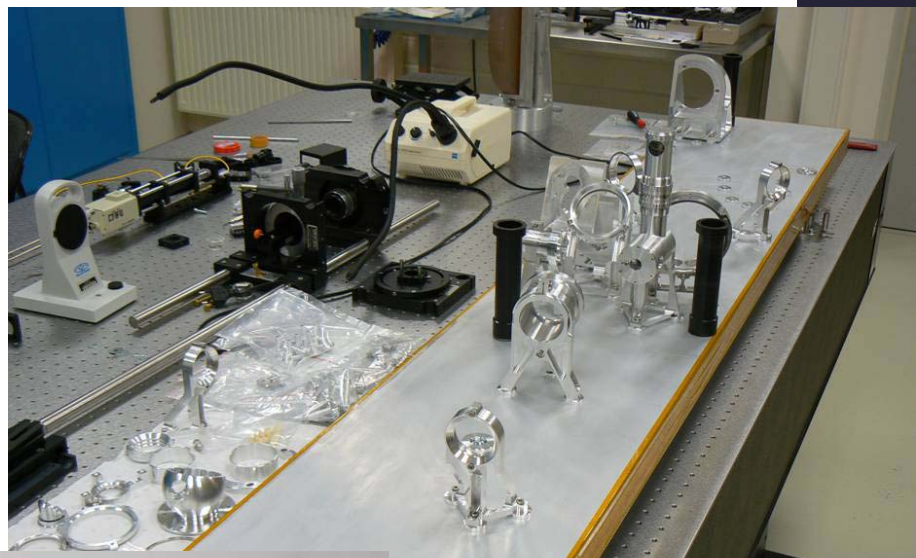
Telescope

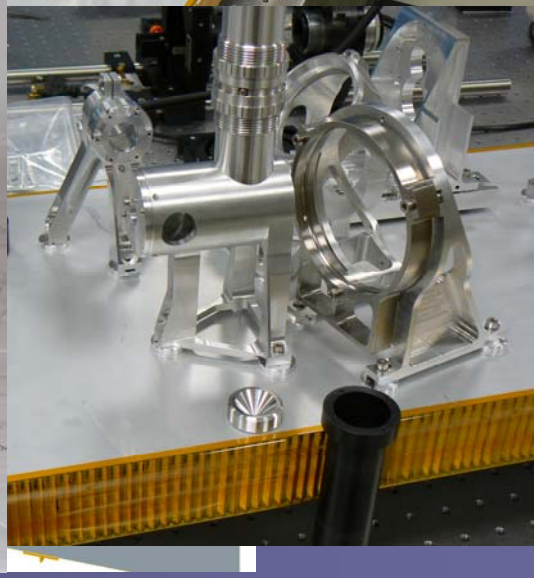
- Mechanisms qualification successfully finished
- Controller electronics qualified and tested
- CFRP qualification program successfully finished in June 2006
- CDR Nov/Dec 2006
- Manufacturing release was given for all components
- Expected delivery date to MPS (including Zerodur primary mirror) May 2008

SUNRISE Hardware Status

Postfocus Instrumentation

- Transition from design phase to manufacturing, assembly and testing
- Lab set-up with flight components in preparation

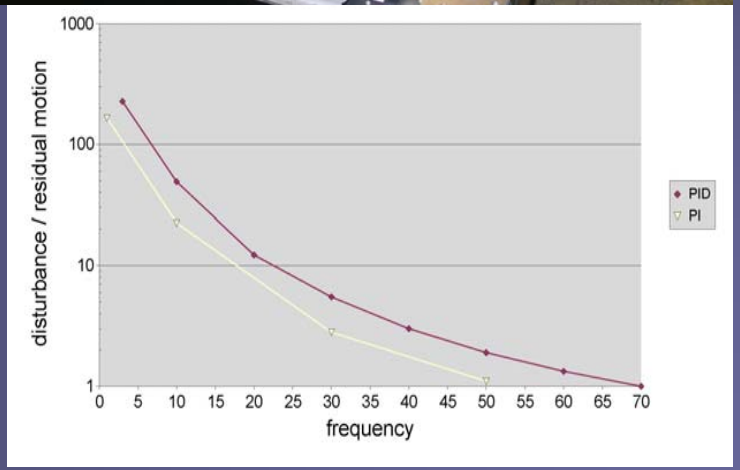




SUNRISE Hardware Status

Wavefront Sensor / Image Stabilization

- Shack-Hartmann sensor with 7 elements, 1.6 kHz frame rate
- Heritage from adaptive optics used at VTT / Tenerife
- Breadboard with flight identical parts qualified and tested in representative setup
- WFE sensitivity 0.05 waves
- Tip/tilt range 120 arcsec, closed loop bandwidth 70 Hz, sensitivity 0.003 arcsec



SUNRISE in Perspective

- Sunrise combines strengths of SST on La Palma (1 m aperture) and of Hinode (spectro-polarimetry with stable image quality).
  This opens new possibilities:
  - Images in the UV down to 0.05″ resolution (factor 2 better than SST)
  - Spectro-polarimetry gains a factor 2 in resolution compared to Hinode
  - Simultaneous high-resolution observations of photo- and chromosphere
- Sunrise improves on Hinode by a factor of 2 - 4 higher spatial resolution: twice larger aperture, up to factor of 4 due to shorter wavelength. Sunrise will detect the underlying structure of Hinode images.
- Sunrise complements Hinode with its UV capability down to 225 nm and with chromospheric spectropolarimetry
- Sunrise will resolve the true photospheric and chromospheric structure underlying SDO-HMI observations and SDO-AIA data

Schedule Milestones (until 1st science flight)

- Preparation flight continental U.S. — Oct 2007
- Primary mirror shipment to KT — Dec 2007
- PFI structure / module integration starts — Jan 2008
- Telescope delivery to MPS — May 2008

- Telescope / PFI integration & calibration finished — Nov 2008
- Gondola / Telescope / PFI integration, system testing until: — Jan 2009
- Ground testing of completed Sunrise system — Feb/Mar 2009

- Mission Readiness Review (MRR) — Feb 2009
- Arrival at ESRANGE/Sweden — Apr 2009
- Launch — Jun 2009

Important to keep this schedule in order to maximize synergy with Hinode

Thank you for your attention